A REAL OPTIONS APPROACH TO BANKRUPTCY COSTS: EVIDENCE FROM FAILED COMMERCIAL BANKS DURING THE 1990S

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by

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Abstract

Literature to date has identified three main aspects of liquidation costs: firm size, asset specificity, and industry concentration. The present paper unifies the theory behind these three aspects of bankruptcy costs by treating them as components of a broader option valuation problem faced by the liquidating trustee. In the options valuation framework, at time *t* the trustee may choose to 1) liquidate at current asset values and incur a known loss, or 2) hold until the next period *t+1* at a positive opportunity cost. The trustee may not sell in the current period if expected asset price growth is sufficiently large. Expectations of asset price growth are based on previous asset price growth and asset price volatility, which are related to firm size, asset specificity, and industry concentration. Testing the hypothesized asset price relationships on FDIC failed bank liquidation data with OLS, three-stage least squares, and duration specifications yields the appropriate results. Furthermore, it appears that liquidation time alone can be used as an effective second order proxy for asset value growth where market value estimates are unavailable.

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Costly bankruptcies hurt creditors and may contribute to sluggish economic growth. Moreover, the substitutability of debt and equity in finance theory is predicated upon low bankruptcy costs. Hence, the financial literature has long sought a better understanding of the costs of bankruptcy.

Though it is generally accepted that direct bankruptcy costs, i.e., legal and administrative fees, are determined primarily by the amount of time spent in liquidation, the determinants of time itself are not well understood. Literature to date has identified three main aspects of liquidation time (and costs): firm size, asset specificity, and industry concentration.[1] The present paper unifies the theory behind these three aspects of bankruptcy costs by treating them as components of a broader option valuation problem faced by the liquidating trustee.

Intuitively, the paper models the trustee's option valuation problem in the following manner. Without loss of generality, assume the trustee bears a fiduciary duty to maximize creditor recoveries. Having taken possession of the firm's assets at a loss to creditors, the trustee's exercise becomes one of loss minimization. At any time t the trustee may choose to 1) liquidate at current asset values and incur a known loss, or 2) hold until the next period $t+1$ at a positive opportunity cost. The trustee will not sell in the current period if expected asset price growth is sufficiently large. Expectations of asset price growth are partially based on asset price volatility, which is itself related to firm size, asset specificity, and industry concentration. Since the option to liquidate is not typically in the money, the trustee will rationally liquidate when marginal gains from waiting approach zero, that is, when the value of the option stabilizes.

The section below describes the options pricing model more formally. Section II introduces the data set. Section III introduces the estimation strategy and assumptions. Section IV presents analysis and results. Section V concludes.

[1] See, for instance, Alderson and Betker (1995; 1996), Warner (1977), and Weiss (1990).

I. The Trustee's Problem

How does the trustee dynamically value the put option on assets in liquidation and how does this behavior affect bankruptcy costs? First, assume the trustee does not face any incentive problems and that there is one uniform portfolio to be liquidated. Then following Dixit and Pindyck (1994), let V equal the current market value of assets to be liquidated. Assume V follows a geometric Brownian motion process such that:

$$\delta V = \alpha V \delta t + \sigma V \delta z \,, \tag{1}$$

where α is a drift parameter, σ is the variance, and δz is the increment of a Wiener process. Equation (1) implies that the current value of the assets is known, but future values are lognormally distributed with a variance that grows linearly with the time horizon.

The trustee's divestment opportunity is equivalent to a perpetual put option. Therefore the decision to divest is equivalent to deciding when to exercise that option.[2] Denote the value of the option to divest as $F(V)$. The trustee chooses the optimal time to exercise such that $F(V)$ is maximized. Let I denote the amount of creditor claims, i.e., the amount that creditors "paid" for the assets. Then the payoff from divesting at any time t is $V_t - I$, and at any time t the trustee's problem is one of maximizing the expected present value:

$$F(V) = \max \mathrm{E}\left[(V_t - I) e^{-\rho T} \right], \tag{2}$$

where E is the expectation operator, T is the (unknown) future exercise date, ρ is the discount rate, and the maximization is subject to (1) for V. It is important to assume that the drift parameter α in (1) remains less than the discount rate ρ. Otherwise waiting longer would always

[2] An American option can be though of as a variant of the perpetual option that is forced to exercise at a limit date. The perpetual option, however, has no such limit date so the exercise needs to be derived from a fundamental limit on the option value. It may be useful to bear in mind the results for a Black-Scholes model of the value of a option on an equity index that pays dividends through the following discussion. The relevant results from that model appear in Appendix B.

be the dominant strategy and no optimum exercise time would exist. Hence, if α is allowed to vary across the business cycle investors would be expected to divest immediately during a cyclical contraction and wait during an expansion.

In the following two sections I present two different solutions to the trustee's problem. A deterministic solution demonstrates that, even in the absence of uncertainty, there may exist value to the creditors from delaying liquidation. Then, a stochastic case is used to illustrate important comparative statics that are tested later in the paper.

A. Deterministic Solution

Suppose σ in equation (1) is zero. Then $V(t)=V_0e^{\alpha t}$ so that, given some current V the value of the divestment opportunity, assuming the trustee divests at some arbitrary future time T, is:

$$F(V) = (Ve^{\alpha T} - I)e^{-\rho T}. \tag{3}$$

Suppose $\alpha \leq 0$. Then $V(t)$ will remain constant or decline over time, implying that it is clearly optimal to divest immediately.

A more interesting result arises when $0 < \alpha < \rho$. Then $F(V) > 0$ even if $V < I$ in the present period because V will *eventually* exceed I. This eventuality arises because although the future value of the initial investment held until T decays at $e^{-\rho T}$, the value of assets to be liquidated decays at the slower rate of $e^{-(\rho-\alpha)T}$.

How long will the trustee therefore wait? Maximizing (3) with respect to T yields the first order condition:

$$T^* = \max\left\{\frac{1}{\alpha}\log\left[\frac{\rho I}{(\rho-\alpha)V}\right], 0\right\}, \tag{4}$$

so that if $V < \frac{\rho}{\rho - \alpha} I$, $T^* > 0$. Growth in V creates value to waiting and increases the value of the trustee's irreversible divestment opportunity.

B. Stochastic Solution

Now suppose $\sigma > 0$. Again, the trustee faces an optimal stopping problem in continuous time. However, since V now evolves stochastically the trustee can no longer derive an optimal divestment time T^*. Instead, the divestment rule will comprise a critical value V^* such that divestment is optimal once $V \geq V^*$. Comparative statics demonstrate that both growth ($\alpha > 0$) and uncertainty ($\sigma > 0$) can create value to waiting and thereby prolong divestment.

The stochastic problem may be solved by dynamic programming. Without loss of generality, assume that the assets under liquidation yield no cash flows up to time T.[3] Then in the continuation region $V < V^*$, the Bellman equation is:

$$\rho F \delta t = \mathrm{E}(\delta F). \tag{5}$$

Expand δF using Ito's Lemma to obtain:

$$\delta F = F'(V)\delta V + \frac{1}{2} F''(V)\delta V^2. \tag{6}$$

Substituting (1) for δV in expression (6) (noting that $\mathrm{E}\delta z = 0$) yields:

$$\mathrm{E}[\delta F] = \alpha V F'(V)\delta t + \frac{1}{2}\sigma^2 V^2 F''(V)\delta t, \tag{7}$$

which can be substituted into (6) to obtain the revised Bellman equation:

$$\frac{1}{2}\sigma^2 V^2 F''(V) + \alpha V F'(V) - \rho F = 0. \tag{8}$$

[3] While this assumption is clearly unrealistic, intermediate cash flows merely complicate the mathematics while leaving the essential comparative static relationships unchanged. See Dixit and Pindyck (1994) for extensions of real options valuation problems that include cash flows.

Optimal V* is determined by solving (8) subject to three boundary conditions. First,

$$F(0) = 0\,, \tag{9}$$

restricts the payoff such that if V goes to zero, the option to invest is worthless. Next,

$$F(V^*) = V^* + I\,, \tag{10}$$

restricts $F(V^*)$ to equal the investment I plus the value of the option V^*. Last,

$$F'(V^*) = 1\,, \tag{11}$$

restricts $F(V)$ to be a smooth continuous function in the region surrounding the exercise value V^*.

The optimal divestment value V^* is obtained by solving (8) subject to the boundary conditions (9), (10), and (11). Equation (9) suggests the solution must take the form:

$$F(V) = AV^{\beta_1}\,, \tag{12}$$

where A is a constant to be determined and $\beta_1 > 1$ is a known constant whose value depends on the parameters σ, ρ, and α in the differential equation (8).

The remaining boundary conditions may be used to solve for the two remaining unknowns, the constant A and the critical divestment threshold V^*. Substitute (12) into (10) and (11) to obtain:

$$V^* = \frac{\beta_1}{\beta_1 - 1} I\,, \tag{13}$$

and

$$A = \frac{V^* - I}{(V^*)^{\beta_1}} = \frac{(\beta_1 - 1)^{\beta_1 - 1}}{\beta_1^{\beta_1} I^{\beta_1 - 1}}\,. \tag{14}$$

The function AV^{β_1} solves equation (8) provided β_1 is a root of the quadratic:

$$\frac{1}{2}\sigma^2 \beta(\beta - 1) + \alpha\beta - \rho = 0\,. \tag{15}$$

The two roots of this quadratic are:

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1,$$

and

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} < 1.$$

The two roots suggest that general solution may be written as $F(V) = A_1 V^{\beta_1} + A_2 V^{\beta_2}$, but boundary condition (9) restricts $A_2 = 0$, leaving the solution as that suggested in (12).

The quadratic expression in general and β_1 in particular are functions of σ, ρ, and α, the parameters for which comparative statics are desired. To illustrate how the root β_1 responds to a change in σ, differentiate the quadratic expression totally. Let Q represent the expression in (15) and β represent β_1 so that the differential with respect to σ can be written:

$$\frac{\partial Q}{\partial \beta}\frac{\partial \beta}{\partial \sigma} + \frac{\partial Q}{\partial \sigma} = 0.$$

Since α and β are both greater than zero:

$$\frac{\partial Q}{\partial \beta} > 0.$$

Then:

$$\frac{\partial Q}{\partial \sigma} = \sigma\beta(\beta - 1) > 0,$$

so it must be that:

$$\frac{\partial \beta}{\partial \sigma} < 0.$$

Thus as σ increases, β decreases and V^* increases so that the greater the uncertainty over future values of V, the larger the return the trustee will seek before irreversibly liquidating the assets.

Because V^* depends not only on the asset price growth α and the discount rate ρ, but on the *difference* between the two, their effects are examined with a slight modification. Let $\delta = \rho - \alpha$ and assume $\delta > 0$. Then the quadratic (15) becomes:

$$\frac{1}{2}\sigma^2\beta(\beta-1) + (\rho-\delta)\beta - \rho = 0, \tag{16}$$

with root β_1:

$$\beta_1 = \frac{1}{2} - \frac{(\rho-\delta)}{\sigma^2} + \sqrt{\left(\frac{(\rho-\delta)}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1.$$

For δ, the differential is then:

$$\underset{(+)}{\frac{\partial Q}{\partial \beta}}\,\underset{(?)}{\frac{\partial \beta}{\partial \delta}} + \underset{(-)}{\frac{\partial Q}{\partial \delta}} = 0,$$

so it must be that

$$\frac{\partial \beta}{\partial \delta} > 0.$$

As δ increases, β increases and V^* decreases so that the greater the discount rate-price growth spread (the higher the opportunity cost to creditors relative to asset price growth), the smaller the return the trustee will seek before irreversibly liquidating the assets.

In summary, the stochastic model optimal divestment value V^* rises in response to greater volatility and declines in response to higher discount rate-price growth spreads. The paper now turns to testing these statics with a large set of data on asset liquidations of bankrupt firms.

II. Data

The theoretical model provides a useful structure for thinking about liquidation decisions. But are these decision variables meaningful in real world applications? The answer to this question hinges on two considerations. First, does data exist that reflect theoretical decision variables available to measure liquidation outcomes? Second, does a model that utilizes these decision variables predict significant variation in liquidation outcomes? The rest of the paper demonstrates that while data for estimating the deterministic model is more readily available than that for estimating the stochastic model, both models provide meaningful estimates of liquidation outcomes.

The present paper measures liquidation outcomes using Federal Deposit Insurance Corporation (FDIC) *Failed Bank Cost Analysis* (FBCA) data on liquidations of 1,581 banks that failed between 1986 and 1996. The FDIC was the majority stakeholder in each case. Therefore in principle the FDIC attempted to extract at least enough value to cover the shortfall incurred from paying depositors (creditors) in full at the time of failure.[4]

Studying liquidation behavior in the banking industry is advantageous for several reasons. First, banks may be thought of as firms with inherently high asymmetric information investments. Evidence for this view is that banking firms not only maintain highly leveraged financial structures to reduce agency and incentive conflicts, but do so by issuing puttable debt

[4] One may argue that the FDIC had little incentive to act as a benevolent trustee, and indeed there exist numerous examples of agency problems at the FDIC and its savings and loan cohort, the Federal Savings and Loan Insurance Corporation (FSLIC), during the period of interest (see, for instance, Kane 1990). However, the FSLIC's bankruptcy and concerns over the FDIC's own solvency may still have been sufficient incentives to pursue a rational liquidation strategy. Behavior in accordance with the options valuation strategy does not require any particular benevolence on the part of the trustee, only triage behavior whereby assets whose values are known to be permanently depressed are sold quickly and those whose conditions are more favorable are delayed. Not enough is known about liquidation behavior to estimate a directional bias that could exist from using FDIC data. Differences in lifetime career horizon and lesser accountability of FDIC officials to taxpayers may favor excess waiting by the FDIC whenever its aggregate workload surges. Nonetheless, the present cross-section data set yields liquidation durations that are comparable with evidence from nonfinancial firms (e.g. Warner (1977) and Weiss (1990)) and suggests expected (lagged) workloads are negatively related with liquidation outcomes, whether measured by asset appreciation or liquidation duration.

that may be redeemed at face value upon demand.[5] It is important to note that while broad categories of bank loans and off-balance sheet positions (such as residual interests in securitizations) are opaque, many bank investments have ascertainable market values. As evidence for this view, Calomiris and Mason (1997, 2003a, and 2003b) establish that sudden exercises of puttable debt, even during events commonly referred to as financial panics, routinely target banks with measurably weak asset portfolios. Hence banks rely upon puttable debt not because their portfolios are impossible to value, but because their portfolios consist largely of industry-specific assets that cannot be easily redeployed elsewhere. Moreover, since private information of the originating bank may be a key determinant of loan value many bank loans may be considered not merely industry-specific assets, but firm-specific assets. Industries that exhibit characteristics of asset specificity are thought to also exhibit extremely wide and deep liquidation cycles (Williamson 1988; Shleifer and Vishny 1992; Alderson and Betker 1996).

Since the opacity of bank assets may obscure the relationship between asset liquidation values and debt capacity, banks have historically insured their puttable debt to stem asymmetric information based panics. When the insurer pays off demandable debt holders in the event of a failure it becomes first claimant on the bank's assets. This serves to concentrate asset value recovery in a single institution, rather than breaking marginal gains throughout different markets and investors. Furthermore, because bank assets are not only industry-, but also institution-, specific (resulting in large price swings) the insurer has an opportunity to capture substantial gains from orderly liquidation.

Finally, because there exists a single liquidator for bank assets in the Federal Deposit Insurance Corporation (FDIC), liquidation proceeds primarily according to the FDIC's

[5] See for instance Calomiris and Kahn (1991).

regulations.[6] Therefore debt cannot be renegotiated as with corporate bankruptcies, there is no holdout problem or violation of absolute priority, and banks do not have an opportunity to “forum shop” for favorable trustees or judges. The absence of these mitigating factors provides a controlled environment for testing whether trustees respond to the fundamental option valuation problem described in the previous section.

The data analyzed in this paper are from the FDIC’s FBCA database and bank Reports of Condition and Income. The FBCA database reports the liquidation progress for individual banks that failed in 1986 and after, and summary data (aggregated by year of failure) for banks that failed before that date. For both individual and aggregate records, the report provides data on the (book value) amount of total assets and liabilities at time of failure, deposit insurance payouts, and the amount recovered up to the date of the report.

Figure 1 represents liquidation outcomes (recoveries) for banks that failed between 1980 and the present. The recoveries represented in Figure 1 are measured at the end of 2000. While it is important to keep in mind that Figure 1 includes results from liquidations that are not yet finished, almost all liquidations that began before 1996 are substantially complete.

On the basis of Figure 1 it is immediately apparent that recoveries associated with failures during periods of banking industry difficulty such as the early and late 1980s were lower than those that occurred in other periods. Recoveries of banks that failed in 1981-1982 averaged 36.5% and recoveries of banks that failed in 1989-1990 averaged 44.1%, whereas recoveries for banks failing in other years over the period 1980-1995 averaged 69.8%, with a maximum aggregate recovery rate from 1995 bank failures of 86.6%.

[6] In practice creditors may petition the FDIC to turn liquidation procedures over to a court-appointed receiver after recoveries are sufficient to cover depositors’ claims. Although common some time ago, this option was rarely exercised in the period of interest.

Such diminished recoveries during periods of economic or industry distress have been noted by other authors on bankruptcy costs and are sometimes thought to be associated with asset fire sales and/or rapid liquidation.[7] Table 1, however, suggests that the fire sale/rapid liquidation hypothesis may not adequately explain these liquidation outcomes. Table 1 presents aggregate FBCA data on both recoveries and liquidation speed. The main body of Table 1 shows the percent of the total recovered amount that is collected in each year of the liquidation. Shaded areas in Table 1 indicate the length of time that liquidation progresses at over five (light) and ten (dark) percent per year. If liquidation slows below that rate and then re-accelerates, the intervening periods are also shaded. Although bank failures after 1997 are included, their liquidations may not have progressed enough to be meaningful.

In contrast to the fire sale/rapid liquidation hypothesis, the rates and shading in Table 1 suggest that the periods of bank failures associated with years of industry distress (and low recovery rates) are associated with *slower* liquidation speed (shading extending further to the right) than those occurring in other years. This coexistence of reduced recoveries and slower liquidations may be the result of a rational application of the options valuation framework described above. First, lower asset values during periods of distress add value to the timing option, so the trustee may rationally delay liquidation. Second, if periods of distress are accompanied by high asset price volatility and high expected price growth in recovery, the option may be quite valuable and the trustee may rationally wait to liquidate.

Is there evidence that bank asset values were more volatile during this period of distress and that expected price growth was particularly high? Can that volatility and price growth be linked to liquidation speed or, more accurately, asset price growth during the period of liquidation?

[7] See, for instance, Pulvino 1998 and Shleifer and Vishny 1992.

For individual banks, the FBCA database provides the date of failure and the date of resolution (if complete). Beginning in 1991, the FBCA report also contains estimated market values of expected final recoveries. These market values were estimated each year by taking a sample portfolio of that year's liquidations and reconciling those values with a statistical model of historical market value estimates maintained at the FDIC.[8] I use changes in these estimated market values to measure asset appreciation across the liquidation period.

The FBCA database does not, however, contain details on bank asset and liability compositions. Furthermore, once a bank fails its charter is retired and each bank is assigned a unique liquidation case number. I therefore hand-matched each bank's liquidation case number to its pre-failure charter number in order to link financial details of each bank at the last observed call prior to failure to the liquidation reports in the FBCA. The resulting cross-sectional data set relates ex ante bank asset and liability compositions to liquidation experiences, measured by both liquidation speeds and asset value growth

The crisis of the 1980s is known to be the result of price volatility among several specific asset classes. The FDIC's own accounts of the crises suggest that the favorable tax treatment for real estate development projects in the Economic Recovery Tax Act of 1981 provided substantial incentive for construction lending.[9] The Tax Reform Act of 1986, however, removed this incentive, reducing the potential profit margins of a substantial number of projects. Additionally, geographic areas that were particularly overbuilt (especially New England and the West) faced additional pressures when the national recession of 1990-91 reduced real estate demand, producing significant declines in rents, prices, and values of all types of real estate properties. Banks experiencing those wide fluctuations in real estate values during the 1980s and 1990s

[8] I thank Richard Brown of the FDIC for providing details on the market value estimation procedure.

[9] See, for instance, Federal Deposit Insurance Corporation (1997, 1998).

were at risk of regulatory action. One way to avoid regulatory attention would be to restore profitability and rebuild capital. Generating high returns that could restore profitability in an environment slipping into nationwide recession entailed taking on more risk. Therefore, it is widely acknowledged risky banks also relaxed loan terms more generally, assuming more credit risk in their commercial and industrial (C&I) loan portfolios. Given the FDIC's anecdotal evidence, I assume that banks' real estate and C&I loan compositions were the primary source of their exposures to volatility and growth expectations that affect the real options problem we want to measure.

Other asset classes were not as volatile during the period of interest. I compare the effects of real estate and C&I loans to consumer loans and government securities to ascertain whether the latter could have been less important to the liquidation of bank portfolios between 1986 and 1996. Banks specializing in new forms of consumer lending and securitization found themselves well-suited to withstand declines in other sectors during the period. Since Treasury rates primarily declined across the period government bonds were good investments.

The composition of these four asset categories is related to liquidation time and asset price growth during liquidation in Tables 2 and 3. The first line of Table 2 shows that the total sample of 1,351 banks that failed between 1986 and 1996 whose *Call Reports* were available has an average liquidation period of 5.6 years. For these 1,351 banks, the average cash and government securities composition (as percent of total assets) is 8.2%, the average consumer loan composition is 12.3%, the average C&I loan composition is 17.1%, and the average real estate loan composition is 14.1%.

The rest of Table 2 reports these asset compositions for cohorts of banks determined by the length of liquidation. Table 2 suggests that cohorts that experienced faster liquidations often had higher average cash and government securities and consumer loan compositions. Banks that completed liquidation in two years had average cash and government securities compositions on the order of eleven percent, while those that went beyond eight years had average compositions of less than six percent. Banks whose liquidations were complete in less than five years had average consumer loan compositions on the order of about twelve to thirteen percent while those that took longer had average consumer loan compositions of around ten percent.

Table 2 also suggests that cohorts that experienced slower liquidations may have had higher C&I and real estate loan compositions. Banks that were liquidated in less than five years generally had average C&I loan compositions of fifteen to sixteen percent. Those that took beyond seven years had average C&I loan compositions of between nineteen and twenty-seven percent. The relationship between real estate lending and liquidation length is less clear. Though the expected relationship between higher real estate lending and longer liquidation exists for liquidations of up to about six years, the relationship is more difficult to interpret for longer periods.

Although the relationships in Table 2 are suggestive, it is important to remember that the options valuation problem more accurately relates more to asset recovery than liquidation time. Table 3 provides more convincing evidence of the rational application of the options valuation approach by relating the asset compositions to asset value growth during liquidation. Because the FBCA only began reporting estimated losses after 1990 and asset appreciation only makes sense for completed liquidations, FBCA asset value estimates are available for only 283 of the 1,351 banks included in Table 2. The overall average liquidation time for the 283 banks in the first line of Table 3 is 4.4 years, the average cash and government securities composition is 6.4%, average consumer loans composition is 12.1%, average C&I loan composition is 14.6%, and average real estate loan composition is 20.2%. The rest of Table 3 reports these asset compositions for cohorts of banks determined by asset appreciation experienced during the liquidation.

If the options valuation model holds, we would expect Table 3 to show that asset appreciation is decreasing in cash and government securities and consumer loans, and increasing in C&I loans and real estate loans. Banks experiencing mild asset appreciation hold average compositions of about six percent cash and government securities while those experiencing more sizeable asset appreciation (greater than 25 percent across the liquidation) are composed of about four percent cash and government securities. Furthermore, banks experiencing mild asset appreciation (zero to 5 percent) hold an average of around thirteen percent consumer loans, while those experiencing greater appreciation (ten to twenty percent) hold around ten percent consumer loans. In contrast, banks experiencing sizeable asset appreciation have average compositions of up to seventeen percent C&I loans and more than twenty-seven percent real estate loans, while those experiencing less asset appreciation are composed of as little as thirteen-and-a-half percent C&I loans and fifteen percent real estate loans.[10]

Though the observations in Tables 2 and 3 are suggestive, they do not provide firm evidence that liquidation proceeded rationally according the option valuation framework described in Section I. Some cohorts in the tables are small and some patterns are non-linear. One trend that is reassuring is that liquidation time is generally increasing in asset appreciation in Table 3. The relationship between these two is important because (as I will demonstrate later) it may be exploited to add power to tests of the real options framework.

In the empirical work that follows, I test the predictions of the options valuation hypothesis using both liquidation time and asset appreciation. First I test the options valuation hypothesis

[10] Additional work also shows that both asset appreciation is positively related to annual and cumulative buy-and-hold returns up to two-and-a-half years prior to bank failure. However the sample size for that analysis is severely limited by the availability of publicly traded stock returns. The results are available from the author upon request.

directly by estimating an ordinary least squares model of asset appreciation. However, the inferences from this model are limited by the small sample size of the data set reported in Table 3. Therefore, I formally demonstrate the correlation between liquidation time and asset appreciation with a three-stage least squares specification that models liquidation time and asset appreciation jointly. I then test whether the correlation between liquidation time and asset appreciation can be exploited to obtain appropriate estimates for the real options variables using liquidation time alone. The survival model used for the final estimates is not limited by the availability of estimated recovery data, so it can use 1,200 of the 1,351 observations reported in Table 2 (151 institutions did not have sufficient financial data available for the survival model). I find that results estimating liquidation time and asset appreciation are similar.

III. Estimation Strategy and Assumptions

I use three different econometric techniques to test how well the options valuation approach fits actual liquidation outcomes. First, I use standard ordinary least squares techniques to estimate the stochastic model relationship between asset price volatility and discount rate – price growth spread and asset price growth over the liquidation. I expect that banks with exposures to higher asset volatilities and lower discount rate – price growth spreads in C&I and real estate loans will yield greater asset price growth over the liquidation.

Second, I estimate a three-stage least squares model that jointly estimates the relationship between asset price volatility and the discount rate – price growth spread, and asset price growth and liquidation time. I find the processes complementary. Liquidation time is positively related to asset appreciation and asset appreciation is positively related to liquidation time, providing evidence that a trustee may rationally lengthen the liquidation to benefit from asset price growth.

Furthermore, high correlation between the two models suggests that liquidation time may be a useful second-order proxy for market value appreciation when this measure is unobservable.

In order to further test the usefulness of liquidation time as a proxy I estimate a duration, or accelerated failure time, model that measures the relationship between asset price volatilities and discount rate – price growth spreads and liquidation times. The drawback of the duration model is that it measures only the amount of time required to liquidate the bank and not the asset price growth. The advantages, however, are that relaxing our reliance upon market value estimates allows us to add observations that occurred before the FDIC began reporting asset value estimates and partial likelihood methods used in duration models allow us to generate inferences from liquidation cases that are as yet unfinished.

The analysis uses a fully parameterized duration model based on a logistic density function. The model is based on the assumption that the two-parameter logistic hazard can be written as:

$$\lambda(t,\alpha,g(x,\beta)) = {g(x,\beta)\alpha t^{\alpha-1}} \Big/ {(1+t^{\alpha}g(x,\beta))},$$

where α is a weighting parameter, t is the length of the spell, and x is a vector of bank and calendar-time specific characteristics. Kiefer (1988) shows that this hazard specification can be used to estimate the log-likelihood function:

$$L(\theta)=\sum_{i=1}^{n} d_i \ln(\lambda(t_i,\alpha,g(x_i,\beta)) - \sum_{i=1}^{n}(1-d_i)\int_0^t (\lambda(t_i,\alpha,g(x_i,\beta)),$$

where d_i is the censoring parameter, by the method of maximum likelihood. The functional form of the covariate effects within the model is specified as:

$$g(x_p,\beta)=\exp(x_i'\beta),$$

which ensures that the hazard is non-negative, and linear in the log of time. This is similar to the assumption of linearity in a standard regression context.

In all specifications, I include both volatility and discount rate – price growth spread measures to accurately capture the dynamics suggested by the options valuation framework. I expect that banks with volatile assets (C&I and real estate loans) will experience longer liquidation times and higher asset value growth than others, while higher discount rate-price growth spreads on those same assets will reduce the asset value growth and time sought by the trustee. All volatility and discount rate – growth spread variables are constructed based on a three-year historical performance window relative to the date of failure. The definitions of all the variables reported in the analysis are summarized in Appendix A.

As described above, real estate and C&I loan values have been attributed particular importance in the causes of bank difficulties in the crisis of the 1980s. Unfortunately, bank assets are renowned for their illiquidity and thin markets. Hence, I incorporate in the empirical work below proxies for the market influences faced by liquidators during this era. In particular, I seek proxies that reflect the types of influences described in the anecdotal accounts of the FDIC and others.

I incorporate the Freddie Mac *Conventional Mortgage Home Price Index* to estimate real estate market fluctuations. Figure 2 shows the quarterly growth rate in the *Index* over the period. The series illustrates how price growth dropped precipitously during 1989 and 1990, negatively affecting bank conditions and significantly increasing the volatility of real estate prices and expectations of future price growth.

The Real Estate Price Volatility variable used below (reflecting σ in the option valuation model) is therefore constructed as the standard deviation of the Freddie Mac *Conventional Home*

Price Index growth rate. I expect Real Estate Price Volatility to be positively associated with asset value growth and liquidation time in the final liquidation outcome.

The Discount Rate – Real Estate Price Growth Spread variable (reflecting δ in the option valuation model) is constructed as the return on the S&P 500 minus the growth rate of the *Index*. Because the spreads are defined as the discount rate minus the growth rate, I expect smaller values of this variable to be associated with higher realized asset value growth and longer liquidation times.

Finding a proxy for C&I loan values is more difficult. Since little market price data exist, I use the profitability of C&I loans in open banks as a proxy for the value of C&I loans affecting closed banks in my sample. I define C&I loan profitability as commercial and industrial loan interest and fee income as a percent of total loans.[11] Evidence of volatility in C&I loan values is presented in Figure 3. The period between from 1990 to 1993 was one of significant decline in C&I loan profitability, which decreased prices on the secondary market and increased volatility and expectations of future price growth in the values of existing C&I loan portfolios.

I construct the C&I Loan Price Volatility variable as the standard deviation of the commercial & industrial loan interest and fee income as a percent of total loans growth rate derived from *Call Report* data. I expect C&I Loan Price Volatility to be positively associated with asset value growth and liquidation time.

I construct the Discount Rate – C&I Loan Price Growth Spread variable as the return on the S&P 500 minus the growth of commercial & industrial loan interest and fee income as a percent of total loans. Again, because the spreads are defined as the discount rate minus the

[11] Both measures are derived from *Call Report* data. I use annual averages to adjust for seasonality.

growth rate, I expect smaller values of this variable to be associated with higher realized asset value growth and liquidation time.

The main purpose of this paper is to measure the effects of asset volatility and discount rate – price growth spreads on asset value growth and the length time during the liquidation to measure whether the results conform to the options value characterization of the liquidation process. In doing so, however, it would be imprudent to omit from the specification other fundamental factors outside the valuation model that are likely to influence the liquidation process. I therefore include several relevant control variables selected from those known to affect bank failure and subsequent direct bankruptcy costs from Calomiris and Mason (2003) and James (1991) respectively. Variables from James (1991) and Calomiris and Mason (2003) that were neither statistically significant nor robust are not included in the models reported here.

The models reported below include a measure of bank size to control for the magnitude of the liquidation process. The present specification utilizes Calomiris and Mason's (2003) log of total assets to account for bank size. Because of the specificity of bank assets, it is not clear that large quantities of bank assets would be easier to sell than small quantities. Hence there may be few economies of scale, or even diseconomies of scale, in liquidating large banks. If this is the case, I expect bank size to be positively related to asset value growth and liquidation time.

James (1991) includes past due and non-accrual loans (as a proportion of total loans) to adjust for past realized losses that may affect the liquidation process. Those past realized losses can be interpreted as an indicator of how truthfully the bank has reported its condition prior to failure. If asset classifications are largely correct there is less asymmetric information between the firm and the trustee and a more rational liquidation strategy can be employed. Hence, if past realized losses are large asset value growth is expected to be higher and liquidation longer.

James' core deposits (as a proportion of total assets) variable is meant to adjust for going-concern value. I utilize a slightly amended version of James' variable from Calomiris and Mason (2003), the ratio of total deposits to total liabilities. The going concern value may be important because banks with larger deposit-to-liability ratios may be more likely to be liquidated through more complex transactions that would take place slowly and entail substantial asset value growth.[12] Hence I expect the total deposits/total liabilities to be positively related to asset value growth and liquidation time.

Other real estate owned (as a proportion of total loans), a useful predictor of bank failure from Calomiris and Mason (2003), is sometimes a statistically significant and economically meaningful addition to the model. Unlike past realized losses, other real estate owned compensates directly for asset quality. Higher proportions of other real estate owned indicate assets tied up on repossessed collateral, which may indicate extremely poor lending policies that could lead to lower asset appreciation and/or shorter liquidations.

As mentioned in the data description, banks in different regions of the U.S. faced heterogeneous asset market conditions in the late 1980s and early 1990s. Therefore I also include regional dummy variables to adjust for differences in average asset value growth and liquidation speeds of banks in these different regions. The excluded region in all specifications is the Southwest. I experimented with interaction variables for the regional dummies and selected controls but the resulting coefficients were not statistically significant and are therefore not reported here.

[12] The FDIC followed at least seven different strategies in liquidating banks, some of which may have destroyed going concern values more than others (see also footnote 14). Of these strategies, a whole-bank purchase and assumption (much like an acquisition) was arguably the least destructive, while a FDIC payoff – in which the FDIC pays off depositors, takes possession of the assets, and fully liquidates – was arguably the most destructive. For more information on resolution strategies, see the *Failed Bank Cost Analysis*.

I also include a dummy variable for bank failures prior to the business cycle trough in 1991 along with interactions of this dummy with the growth spread and volatility proxies. As suggested by Shleifer and Vishny (1992) and Kiyotaki and Moore (1995), if trustees are concerned with price volatility and expected asset value growth their strategies may differ with the stages of the business cycle. I expect banks failing as the economy is slowing prior to the business cycle trough of March 1991 may be liquidated faster than those that fail during the subsequent economic upswing.

IV. Analysis and Results

This section reports results of the OLS, three-stage least squares, and duration models that quantitatively measure relationships between volatility and discount rate – price growth spreads, and asset price growth and liquidation time. Overall, I find evidence of a rational application of the trustee's problem in Section I. Banks exposed to volatile assets or assets with low discount rate – price growth spreads generally take longer to liquidate and yield a greater value appreciation (higher V^*) than others. Moreover, OLS estimates of the stochastic model are correlated with the results of the three-stage least squares and the duration models, suggesting that liquidation time may provide a useful proxy for applying the options valuation approach in the real world, where market value asset appreciation may be difficult to measure.

A. OLS Model of Asset Value Growth

Table 4 presents results of asset value growth model for the 276 completed bank liquidations that began after 1990. The asset volatility and discount rate – price growth spread variables alone (Column 1) explain 9.2 percent of the variation in asset value growth in the present sample. In Column 1, the C&I Loan Price Volatility, the Discount Rate-C&I Loan Price Growth Spread, and the Real Estate Price Volatility variables all obtain the correct signs and are statistically significant. The coefficient on the Discount Rate-Real Estate Price Growth Spread is statistically insignificant.

The specification in Column 2 adds the control variables.[13] The addition raises the adjusted r-squared of the specification (to 10.3 percent), and the signs on all of the real options valuation variables obtain the correct signs. However, only the coefficient on Real Estate Price Volatility remains statistically significant at conventional levels. Bank size is positively associated with asset value growth , V^*, and banks located in the Southeast realize lower asset value growth than those in the Southwest (the omitted group).

The results in table 4 are intriguing, but the small sample size and restriction to banks that failed only after 1990 could be limiting the model's ability to deliver the expected results. If we can establish that liquidation time, T^*, is closely correlated with asset appreciation, V^*, we can explore the options valuation model further. We begin that exercise by modeling both asset appreciation, V^*, and liquidation time, T^*, together in a three-stage least squares specification.

B. Three-Stage Least Squares Model of Asset Appreciation and Time

Table 5 again relies on the restricted sample of 272 completed bank liquidations beginning after 1990. However, here I estimate a process where both asset appreciation and liquidation time are believed to be determined jointly by asset volatilities and discount rate – price growth spreads, the control variables, and each other. I use different liquidation strategies employed by the FDIC as exogenous variables.[14] The three-stage least squares system in Table 5 explains

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[13] Note that four observations are lost in column 2's specification due to missing control variables.

[14] Although I posit that FDIC bank liquidations may have been carried out in a manner that is similar to that suggested by the real options strategy, there is reason to believe that this was not a conscious strategy on the part of the FDIC. It is well known that the FDIC was subject to myriad political and economic pressures, sometimes to keep banks open and other times to close them promptly (see for instance, Kane and Yu 1995). Similar pressures affected the liquidation strategy chosen by the FDIC, providing an identifying influence that should be exogenously related to liquidation time. The liquidation strategies used as instruments are: FDIC Assisted Transactions; Insured Deposit

more than 48 percent of the combined variation in asset value growth and liquidation time and the two processes have a correlation coefficient of 0.26.

The results for asset value growth reported in Table 4 are robust to jointly estimating liquidation time in Table 5. All asset volatility and discount rate – price growth spread variables obtain the correct signs. Again, bank size and location in the Southeast are statistically significant control variables.

The results of the liquidation time specification in Column 2 seem even stronger than those for asset value growth (which may be affected by errors in the FDIC market value estimation process). Both the Discount Rate – Real Estate Price Growth and Discount Rate – C&I Loan Price Growth Spread variable coefficients are negative and statistically significant. Coefficients on the C&I Loan and Real Estate Price Volatility variables are positive and statistically significant.

Coefficients on control variables for Log of Total Assets, Past Due and Non-Accrual Loans, and Other Real Estate Owned are all statistically significant. Since the Log of Total Assets reflects bank size and liquidation time is positively related to asset value growth , it makes sense that larger banks would take longer to liquidate. If Past Due and Non-Accrual Loans accurately reflects past realized losses and liquidation time is related to asset value growth , then again it makes sense that an orderly liquidation of a poorly performing, though accurately disclosed, portfolio should take longer than otherwise and ultimately lead to higher asset value growth . Other Real Estate Owned, reflective of poor credit quality, is also associated with longer liquidation times. Among the regional indicator variables, liquidations in the Northeast and West took longer, on average, than those in the Southwest.

Purchase and Assumptions (P&As); Partial Bank P&As; Whole Bank P&As; Deposit Insurance Transfers; and Deposit Insurance Transfers w/ Asset Purchases. Direct FDIC Payoffs are the excluded indicator category.

The endogenous liquidation time and asset appreciation variables are insignificant in Columns 1 and 2, respectively, suggesting that the real options and control variables adequately capture the endogenous effects. Given the positive correlation coefficient between the two processes and the performance of the liquidation model, liquidation time may indeed serve as a useful second order proxy for asset value growth. The next section compares estimates of liquidation time in isolation and conjectures whether the expanded sample available for such an analysis can further confirm the options valuation approach.

C. Duration Model of Liquidation Time

The first column of Table 6 contains duration estimates of liquidation time based on the previously analyzed sample of 272 completed liquidations that began after 1990. Although the sample size in Column one remains small, all the volatility and discount rate – price growth spread variables obtain the correct signs and are statistically significant. Past Due and Non-Accrual Loans and Other Real Estate Owned are again positive and statistically significant.

In Column 2, duration analysis is used to test the relationship between these variables and liquidation time further using all 1,200 observations in the data set from 1986 to 1996.[15] Here, the log of Total Assets (bank size) and Total Deposits/Total Liabilities variables are associated with longer liquidation times. Furthermore, the C&I Loan Price Volatility and Discount Rate – C&I Loan Price Growth Spread variables again obtain the correct signs and are statistically significant. However, the Real Estate Price Volatility and Discount Rate – Real Estate Price Growth Spread variables obtain the wrong sign and are statistically significant.

[15] The vastly different sample sizes result because the previous models rely crucially upon estimated recovery data, which the FDIC only archived after 1990, to accurately measure asset appreciation, *V**. The earlier OLS was also estimated using 1991 estimated recovery data for banks failing before that year. The reported results were qualitatively robust to the data adjustment. FBCA data is not available before 1986.

Considering the period 1986-1996 encompasses a full business cycle, whereas the period 1991-1996 was only an economic expansion, the sign change may not be surprising. Shleifer and Vishny (1992) and Kiyotaki and Moore (1995) suggest theoretically that liquidation behavior may differ according to the direction of the economy. To test this conjecture, Column 3 adds the Pre-Trough Indicator (a peak-to-trough indicator variable) and allows the coefficients on the volatility and discount rate – price growth spread variables to vary across the business cycle.

The coefficients on the original Real Estate Price and C&I Loan Price Volatility and Discount Rate – Real Estate Price Growth and Discount Rate – C&I Loan Price Growth Spread variables in Column 3 again obtain their appropriate signs in the presence of the Pre-Trough Indicator and interaction variables. This result obtains because the original variables now reflect real option valuation only during the business cycle growth period. The signs on the Real Estate Price and C&I Loan Price Volatility and Discount Rate – Real Estate Price Growth and Discount Rate – C&I Loan Price Growth Spread interaction variables (reflecting the contractionary period) are exactly *opposite* those of their expansionary counterparts.

This result suggests that the options valuation problem may also depend upon the direction the economy. Only the volatility coefficients are significant in this specification, and the signs on volatility are negative in falling markets (suggesting quick disposal of volatile assets) and positive in expanding markets (suggesting delayed disposal of volatile assets). Hence it appears that volatility is a double-edged sword, benefiting the trustee in expansionary periods but posing a risk of prolonged exposure to depressed asset values in contractionary periods.

V. Summary and Conclusions

This paper establishes a basis for considering the established determinants of bankruptcy costs as components of a real options valuation problem wherein asset price expectations may lead trustees to rationally delay liquidation and incur more direct costs. In the real options framework, expectations of asset price growth are based upon past asset price growth and volatility, which are themselves related to firm size, asset specificity, and industry concentration, all of which are established determinants of bankruptcy costs.

The paper derives testable implications from a real options framework and demonstrates empirically that the optimal divestment threshold rises in response to greater volatility and lower discount rate – price growth spreads. That is, if trustees experience greater price volatility and higher price growth (net of the discount rate on alternative investments), they may rationally delay liquidation awaiting greater price growth. Banks with high levels of volatile assets and assets with higher price growth (net of the discount rate on alternative investments) are therefore expected to yield a greater value appreciation (higher V^*) over the course of a longer liquidation (higher T^*) than others.

The paper formally tests the relationships between volatility and discount rate – price growth spreads, and asset price growth and liquidation thresholds with a large set of data on liquidations of failed banks during the 1980s and 1990s. This analysis yields three main conclusions.

First, OLS models that directly measure determinants of asset appreciation support the hypothesis that the stochastic options valuation problem is related to bankruptcy costs. Banks with high levels of volatile assets and lower discount rate-price growth spreads generally yield a greater value appreciation (higher V^*), than others.

Second, results of the three-stage least squares specification suggest liquidation time is correlated with value appreciation. The primary implication of this result is that in some cases liquidation time may be used as a second order proxy for value appreciation where estimates of market values are unavailable.

Third, results of the survival model illustrate that the observed implications of the options valuation problem may vary across the business cycle. Trustees may liquidate volatile assets faster (at lower asset value growth) in business cycle contractions and slower (at higher asset value growth) in business cycle expansions.

From a public policy perspective, there exist two additional implications. First, liquidation differences across the business cycle could be a source of a substantial procyclicality, whereby fast liquidations when the economy is contracting may help push prices downward, heightening price volatility, economic uncertainty, and business cycle depth and persistence. Second, the results show the importance of reflationary monetary policy following recessions. Reflation can effectively push up discount rates in the model, thereby increasing discount rate – price growth spreads and promoting the sale and redeployment of assets in liquidation. More research will be necessary to determine the importance of these effects.

In conclusion, there appears to be evidence that the real options approach is a sensible way to think about liquidation decisions and bankruptcy costs. However, there remains room for additional empirical work that can implement more diverse (nonbank) samples and market value proxies across the business cycle to further establish the robustness of the hypothesized relationships between asset volatility and discount rate – price growth spreads, and liquidation time and asset value growth .

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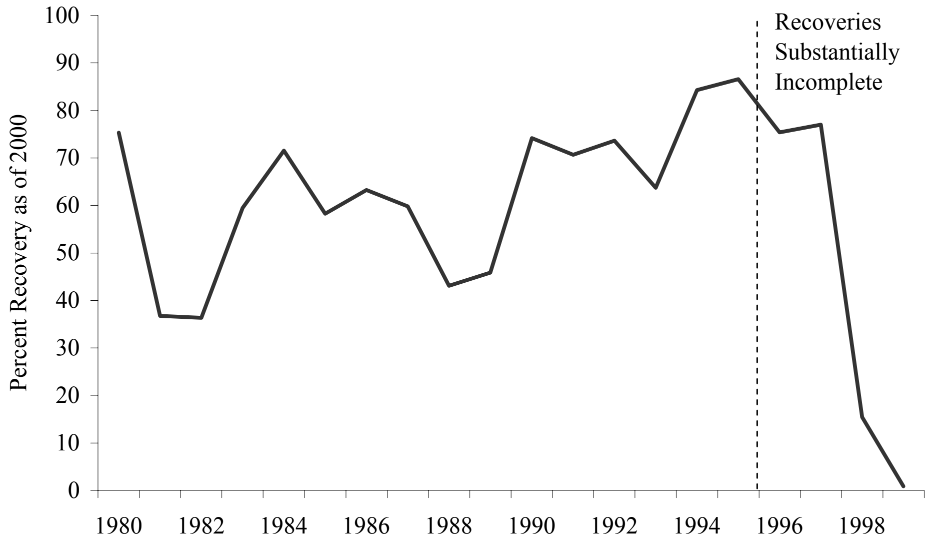
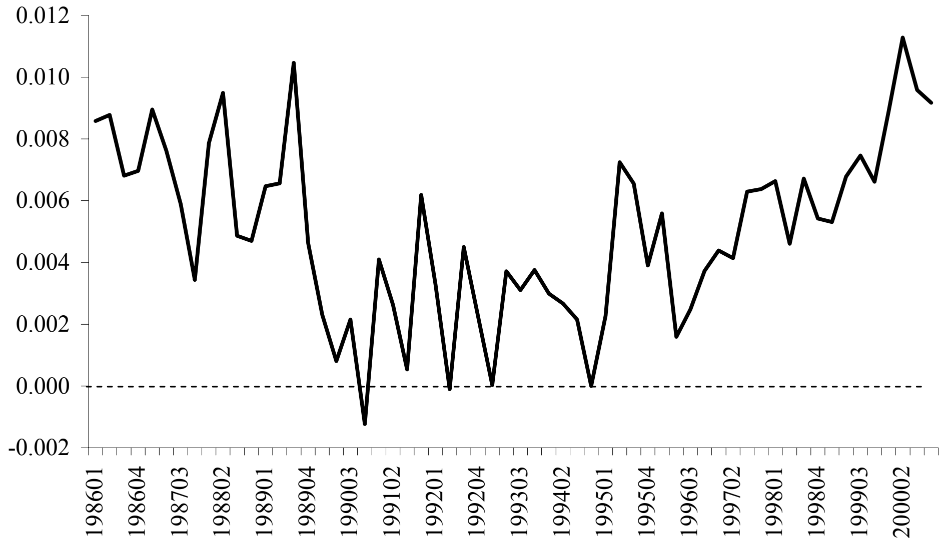
Figure 1: Total Recoveries to FDIC Bank Liquidations, 1980-2000



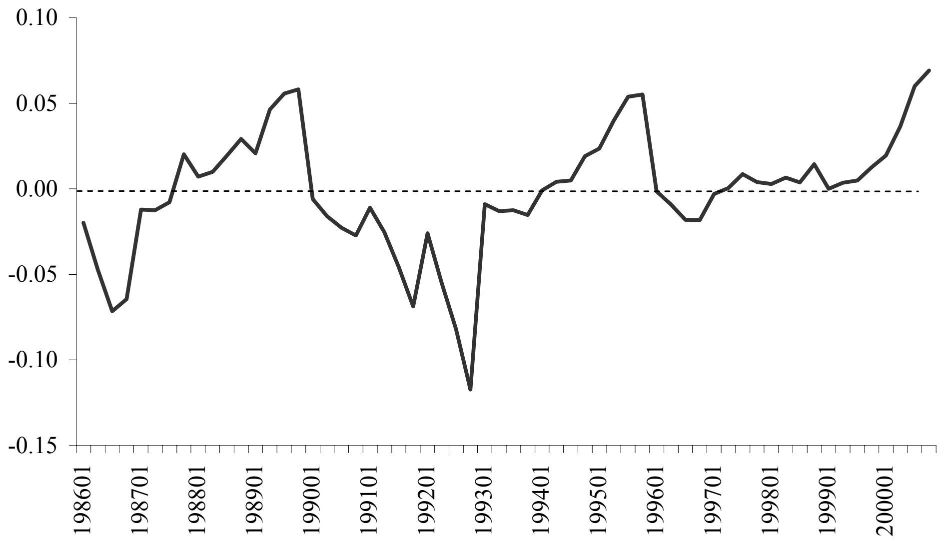
Source: *FDIC Failed Bank Cost Analysis* , Various Years.

Figure 2: Quarterly Growth Rate, Freddie Mac Conventional Mortgage Home Price Index, 1986-2000



Source: Freddie Mac Second Quarter 2001 release.

Figure 3: Quarterly Growth Rate of Commercial and Industrial Loan Profitability, 1986-2000



Source: Commercial Bank *Call Reports* , Interest and Fee Income On Commercial and Industrial Loans divided by Total Commercial and Industrial Loans To U.S. and Non-U.S. Addresses for the Consolidated Bank.

Table 1: Annual Number, Size, and Progress of Bank Liquidations, 1980-2000

			Annual Percent of Total Recovery in Each of Years After Failure											
Failure Year	Number of New Failures	Disbursements ($ thousands)	0	1	2	3	4	5	6	7	8	9	10	Total Recovery, 2000 (%)
1980	11	$152,355	31.64	27.95	19.22	4.87	4.93	5.53	2.98	1.77	0.53	0.60	0.00	75.32
1981	10	888,999	25.03	59.19	4.30	4.23	3.32	0.54	2.21	0.69	0.02	0.47	0.00	36.75
1982	42	2,275,150	14.14	18.11	11.08	11.70	6.52	9.74	2.64	28.18	0.24	-2.15	-0.20	36.36
1983	48	3,807,082	23.68	25.68	9.44	9.55	10.79	7.30	3.42	1.30	2.14	5.92	0.78	59.47
1984	80	7,696,215	50.86	8.41	10.02	7.06	9.38	3.93	6.10	1.48	2.55	0.15	0.05	71.55
1985	120	2,920,687	26.24	27.22	18.74	12.76	3.84	1.57	0.02	3.41	4.73	0.22	1.26	58.26
1986	145	4,790,969	26.04	34.42	15.55	8.31	4.46	0.77	7.66	1.94	0.75	0.00	0.10	63.24
1987	203	5,037,871	22.81	40.61	12.28	7.58	6.29	4.83	2.58	0.94	0.87	0.65	0.56	59.79
1988	221	12,163,006	32.11	31.22	2.25	5.12	5.12	5.12	0.45	0.40	0.90	16.86	0.43	43.07
1989	207	11,445,829	33.37	35.52	18.00	0.64	0.64	0.64	1.04	6.43	2.72	0.46	0.55	45.84
1990	169	10,816,602	19.15	56.58	7.53	9.44	1.37	0.53	3.19	1.23	0.72	0.25		74.19
1991	127	21,412,647	29.21	22.49	36.97	6.48	1.39	0.61	-1.74	3.18	1.41			70.68
1992	122	14,084,663	26.74	34.88	28.54	1.09	2.71	2.71	2.29	1.05				73.64
1993	41	1,797,297	71.35	8.19	12.10	2.28	2.28	3.12	0.68					63.73
1994	13	1,224,797	22.16	34.18	19.07	22.02	1.60	0.96						84.28
1995	6	609,045	55.03	16.95	24.42	3.59	0.00							86.58
1996	5	169,397	0.00	88.31	4.04	7.65								75.41
1997	1	25,546	0.00	97.26	2.74									77.00
1998	3	285,763	12.29	87.71										15.46
1999	7	1,234,278	100.00											0.90
	1581	$102,838,198												

Sources: FDIC Annual Reports and Author's Calculations. Note: In most cases prior to 1996, Total Recovery reflects the percent of total claims that were recovered during the entire period of liquidation. Total Recoveries after 1996 are more substantially incomplete. Negative recoveries may arise when banks return some assets previously purchased from the FDIC under put-back options. Dark shading indicates period over which liquidation proceeds at ten percent per year. Lighter shading indicates progress of five percent per year.

Table 2: Asset Composition of Failed Banks, By Resolution Time, 1986-1996

Resolution Length (Years)	N	Average Resolution Length	Average Cash and Gov't Securities	Average Consumer Loans	Average Commercial and Industrial Loans	Average Real Estate Loans
All Banks:						
na	1351	5.621	0.082	0.123	0.171	0.143
Finished Resolutions:						
2	14	1.594	0.115	0.086	0.161	0.100
3	118	2.573	0.095	0.129	0.153	0.109
4	157	3.484	0.082	0.126	0.153	0.127
5	208	4.539	0.075	0.132	0.153	0.140
6	201	5.470	0.076	0.138	0.168	0.165
7	178	6.450	0.077	0.132	0.184	0.139
8	155	7.486	0.097	0.111	0.192	0.128
9	100	8.468	0.061	0.112	0.190	0.131
10	33	9.434	0.072	0.101	0.243	0.168
11	20	10.440	0.058	0.100	0.272	0.124
Unfinished Resolutions:						
na	70	6.530	0.106	0.075	0.148	0.252

Source: FDIC Reports of Condition and Income and FDIC Failed Bank Cost Analysis (various years). All asset categories are expressed as a proportion of total assets.

Table 3: Average Asset Composition of Post-1990 Failed Banks with Complete Resolutions, by Asset Appreciation

Asset Appreciation (Percent)	N	Average Resolution Length	Average Cash and Gov't Securities	Average Consumer Loans	Average Commercial and Industrial Loans	Average Real Estate Loans	Average Asset Appreciation (Decimal)
All Banks:							
na	283	4.381	0.064	0.121	0.146	0.202	0.023
Finished Resolutions (Post-1990 Failures Only):							
x<0	123	4.117	0.069	0.113	0.150	0.213	-0.100
5>x>=0	67	4.200	0.061	0.132	0.135	0.153	0.019
10>x>=5	35	4.966	0.057	0.149	0.148	0.234	0.072
15>x>=10	16	4.620	0.074	0.096	0.170	0.228	0.127
20>x>=15	11	4.109	0.081	0.115	0.154	0.271	0.178
25>x>=20	11	4.899	0.071	0.094	0.128	0.193	0.227
>=25	20	5.180	0.044	0.123	0.148	0.199	0.383

Source: FDIC Reports of Condition and Income and FDIC Failed Bank Cost Analysis (various years). All asset categories are expressed as a proportion of total assets.

Table 4: OLS Estimates of Asset Appreciation, 1991-1996 Failed Banks with Complete Resolutions

	(1)		(2)	
Model Type: Independent OLS				
n	276		272	
R^2	0.105		0.146	
Adjusted R^2	0.092		0.103	
Independent Variable: Asset Appreciation	Coefficient *Std. Err.*		Coefficient *Std. Err.*	
Constant	-0.290	**	-0.685	***
	(0.146)		*(0.292)*	
C&I Loan Price Volatility	125.703	**	76.972	
	(73.767)		*(80.658)*	
Discount Rate - C&I Loan Price Growth Spread	-0.011	*	-0.007	
	(0.007)		*(0.007)*	
Real Estate Price Volatility	79.723	*	85.694	*
	(51.134)		*(52.802)*	
Discount Rate - Real Estate Price Growth Spread	8.12E-06		-7.04E-05	
	(0.004)		*(0.004)*	
Log of Total Assets			0.015	**
			(0.008)	
Past Due and Non-Accrual Loans / Total Loans			0.040	
			(0.097)	
Other Real Estate Owned / Total Loans			-0.087	
			(0.137)	
Total Deposits / Total Liabilities			0.180	
			(0.154)	
Central			0.031	
			(0.057)	
Midwest			0.055	
			(0.049)	
Northeast			-0.005	
			(0.026)	
Southeast			-0.053	*
			(0.038)	
West			-0.027	
			(0.030)	

*** = Statistical Significance at $\alpha = 0.01$

** = Statistical Significance at $\alpha = 0.05$

* = Statistical Significance at $\alpha = 0.10$

Table 5: 3SLS Estimates of Resolution Time and Asset Appreciation,1991-1996 Failed Banks with Complete Resolutions

Model Type:	3SLS			
n	272			
R^2 (System-wide for 3SLS)	0.487			
Correlation between dependent variables:	0.259			

Independent Variable:	(1) Asset Appreciation Coefficient *(Std. Err.)*		(2) (log) Liquidation Time Coefficient *(Std. Err.)*	
Constant	-0.869		4.135	***
	(0.813)		*(0.333)*	
C&I Loan Price Volatility	71.615		474.145	***
	(83.564)		*(93.727)*	
Discount Rate - C&I Loan Price Growth Spread	-0.006		-0.027	***
	(0.007)		*(0.008)*	
Real Estate Price Volatility	82.317	*	693.164	***
	(54.567)		*(61.216)*	
Discount Rate - Real Estate Price Growth Spread	-4.00E-05		-0.008	*
	(0.004)		*(0.005)*	
Log of Total Assets	0.015	**	0.018	**
	(0.008)		*(0.009)*	
Past Due and Non-Accrual Loans / Total Loans	0.040		0.318	***
	(0.097)		*(0.110)*	
Other Real Estate Owned / Total Loans	-0.084		0.512	***
	(0.137)		*(0.156)*	
Total Deposits / Total Liabilities	0.178		0.022	
	(0.154)		*(0.175)*	
Length of Liquidation (Endogenous)	0.027			
	(0.110)			
Asset Appreciation (Endogenous)			0.407	
			(0.456)	
Central	0.032		0.057	
	(0.058)		*(0.065)*	
Midwest	0.057		0.003	
	(0.050)		*(0.056)*	
Northeast	-0.006		0.073	***
	(0.026)		*(0.030)*	
Southeast	-0.054	*	-0.022	
	(0.039)		*(0.044)*	
West	-0.027		0.047	*
	(0.030)		*(0.034)*	

*** = Statistical Significance at $\alpha = 0.01$

** = Statistical Significance at $\alpha = 0.05$

* = Statistical Significance at $\alpha = 0.10$

Table 6: Duration Estimates of Liquidation Time

Loglinear Survival Model: Logistic			
Dependent Variable (All Models):		(log) Liquidation Time	
	(1)	(2)	(3)
Log Likelihood	82.2	-437.0	-335.9
Log Likelihood (coef=0)	-20.2	-654.8	-654.8
LR Test of Sig. (χ^2_k)	204.8	435.5	637.6
Significance Level	0.00	0.00	0.00
Number of Total Obs.	272	1200	1200
Number of Obs. Still Active	0	64	64
	Coefficient *Std. Err.*	Coefficient *Std. Err.*	Coefficient *Std. Err.*
Constant	4.266 ***	5.736 ***	2.341 ***
	(0.367)	*(0.274)*	*(0.426)*
C&I Loan Price Volatility	502.935 ***	0.013 ***	297.175 *
	(90.533)	*(0.001)*	*(186.658)*
Discount Rate - C&I Loan Price Growth Spread	-0.029 ***	-0.012 ***	-0.012
	(0.008)	*(0.001)*	*(0.017)*
Real Estate Price Volatility	719.644 ***	-335.088 ***	693.440 ***
	(55.149)	*(32.298)*	*(123.463)*
Discount Rate - Real Estate Price Growth Spread	-0.007 *	0.042 ***	-0.008
	(0.005)	*(0.004)*	*(0.010)*
C&I Loan Price Volatility * Pre-Trough Indicator			-297.174 *
			(186.658)
Discount Rate - C&I Loan Price Growth Spread * Pre-Trough Indicator			0.011
			(0.017)
Real Estate Price Volatility * Pre-Trough Indicator			-770.667 ***
			(135.029)
Discount Rate - Real Estate Price Growth Spread * Pre-Trough Indicator			0.013
			(0.012)
Log of Total Assets	0.005	0.108 ***	0.118 ***
	(0.008)	*(0.009)*	*(0.009)*
Past Due and Non-Accrual Loans / Total Loans	0.229 ***	0.036	0.034
	(0.091)	*(0.089)*	*(0.086)*
Other Real Estate Owned / Total Loans	0.370 ***	0.086	0.134
	(0.144)	*(0.122)*	*(0.119)*
Total Deposits / Total Liabilities	0.058	0.310 **	0.430 ***
	(0.225)	*(0.177)*	*(0.146)*
Pre-Trough Indicator			*2.987* ***
			(0.358)
Central	0.075	-0.087	-0.065
	(0.052)	*(0.055)*	*(0.050)*
Midwest	0.095	-0.356	-0.363
	(0.061)	*(0.029)*	*(0.027)*
Northeast	0.080	-0.105	-0.066
	(0.028)	*(0.044)*	*(0.043)*
Southeast	0.043	-0.078	-0.051
	(0.037)	*(0.051)*	*(0.048)*
West	0.047	-0.133	-0.064
	(0.027)	*(0.028)*	*(0.029)*

*** = Statistical Significance at $\alpha = 0.01$

** = Statistical Significance at $\alpha = 0.05$

* = Statistical Significance at $\alpha = 0.10$

Appendix A: Variable Definitions

Resolution Length – Number of years between a bank's failure and final resolution of the bank's assets and liabilities.
Cash and Gov't Securities – Sum of the bank's cash and due from depository institutions, U.S. Treasury securities, and U.S. Agency securities, divided by total assets.
Consumer Loans – Sum of the bank's credit card lending, other consumer lending, and home equity lines of credit divided by total assets.
Commercial and Industrial Loans – Sum of the bank's U.S. and non-U.S. commercial and industrial loans divided by total assets.
Real Estate Loans – Sum of the bank's real estate construction and development loans, multifamily real estate loans, nonfarm nonresidential property, and commercial real estate loans divided by total assets.
Asset Appreciation – Log difference between the initial FDIC recovery estimate and the actual final recovery at the end of liquidation.
C&I Loan Price Volatility – Three-year standard deviation of the commercial & industrial loan interest & fee income as a percent of total loans growth rate (annual average of quarterly *Call Report* data) over the period prior to bank failure.
Discount Rate – C&I Loan Price Growth Spread – Three-year return on the S&P 500 minus the three-year growth of commercial & industrial loan interest & fee income as a percent of total loans (annual average of quarterly *Call Report* data) over the period prior to bank failure.
Real Estate Price Volatility – Three-year standard deviation of the Freddie Mac *Conventional Home Price Index* growth rate over the period prior to bank failure.
Discount Rate – Real Estate Price Growth Spread – Three-year return on the S&P 500 minus the three-year growth rate of the Freddie Mac *Conventional Home Price Index* over the period prior to bank failure.
Pre-Trough Indicator – Indicator variable for failures occurring prior to the business cycle trough of March 1991.
Log of Total Assets – Size of the bank measured as the natural log of total assets.
Past Due and Non-Accrual Loans / Total Loans – Sum of 30-89 day past due, 90+ day past due, and non-accrual loans as a proportion of total loan and leases.
Other Real Estate Owned / Total Loans – Real estate owned (other than bank premises) as a proportion of total loans and leases.
Total Deposits / Total Liabilities – Total bank deposits as a proportion of total liabilities.
Central – Regional indicator variable for banks located in the states of MI, WI, KY, OH, IN, and IL.
Midwest – Regional indicator variable for banks located in the states of SD, ND, NE, IA, MN, MO, and KS.
Northeast – Regional indicator variable for banks located in the states of DE, MD, ME, PR, RI, VT, PA, DC, NJ, NH, NY, CT, and MA.
Southeast – Regional indicator variable for banks located in the states of SC, GA, MS, NC, WV, AL, TN, VA, and FL.
West – Regional indicator variable for banks located in the states of ID, OR, HI, WA, AK, UT, MT, WY, AZ, CO, and CA.

Appendix B: Black Scholes European Analogue to the Real Options Results

The propositions of the real options model can be related to a more standard Black-Scholes option valuation model. The appropriate Black-Scholes variant to consider here is that for a European option on a stock index that pays dividends. Since the value of an American option is bounded below by the value of a European option, we can use the Black-Scholes results to help better explain the intuition behind the testable propositions of the real options model. The Black-Scholes specification for a European option on a stock index paying dividends is:

$$c = S_0 e^{-qT} N(d_1) - X e^{-rT} N(d_2),$$

where…

$$d_1 = \frac{\ln(S_0 / X) + (r - q + \sigma^2 / 2)T}{\sigma\sqrt{T}},$$

$$d_2 = \frac{\ln(S_0 / X) + (r - q - \sigma^2 / 2)T}{\sigma\sqrt{T}}.$$

In a standard Black-Scholes valuation model without dividends, the *r* accounts for time decay resulting from the opportunity cost of the option investment. With dividends, the term *r-q* accounts for decay in the value of the option with respect to a risk-free rate *net of appreciation in the value of the position due to a constant dividend payment rate, q*. The difference between these two, that is, the discount rate minus the growth rate, is the spread variable δ in the real options model. These two spread components would be expected to have opposite signs if they entered the specification independently since one is an instrument of decay and the other an instrument of appreciation, and comparative statics of the Black-Scholes model with dividends establish these signs as routine results from the first derivatives:

$$\frac{dc}{dr} = XTe^{-rT} N(d_2),$$

and

$$\frac{dc}{dq} = -S_0 Te^{-qT} N(d_1).$$

Note that the signs relate to the value of the option, so that a higher discount rate increases the option value (and makes early exercise more likely in an American or perpetual application) and a higher growth rate decreases the option value (and makes early exercise less likely in an American or perpetual application). When included in the present empirical specification independently, the variables do in fact yield the appropriate signs (negative for the discount rate and positive for the growth rate).

It is not clear, however, that allowing the spread components to enter independently in the real options model is theoretically justified. In the present application the relevant concept is the spread between the discount rate and the growth rate. This is because there may instances where value growth is high, suggesting liquidators should wait. But if the discount rate is also high, liquidation should be accelerated. If, given the same value growth rate, the discount rate is low, liquidation should be delayed. Hence, the relevant concept for the real options model appears to be the spread, rather than the independent discount and growth variables.